AECC

AUTOMOTIVE EDGE COMPUTING CONSORTIUM

WHITE PAPER

Digital Twins

June 2024 v1.0

Contents

Introduction

Accurate digital representations of real-world entities are vital in various business sectors, as simulation and prediction are becoming key building blocks for advanced services. The automotive sector is one of those promising to benefit from such fine-grained digital representations. Data on roads, vehicles and other road entities, collected from various sources, would enable many new services. One paradigm for structuring data as a digital reconstruction of the physical entities is called the “Digital Twin.” To allow the digital twin concept to be utilized for automotive use cases, it is crucial to collect data, integrate it and give structure to it, which makes data interpretation more efficient. Furthermore, structured data gives more business value. This document introduces the automotive use cases of digital twins. This document also briefly addresses the benefits and challenges of edge implementation.

About Digital Twins

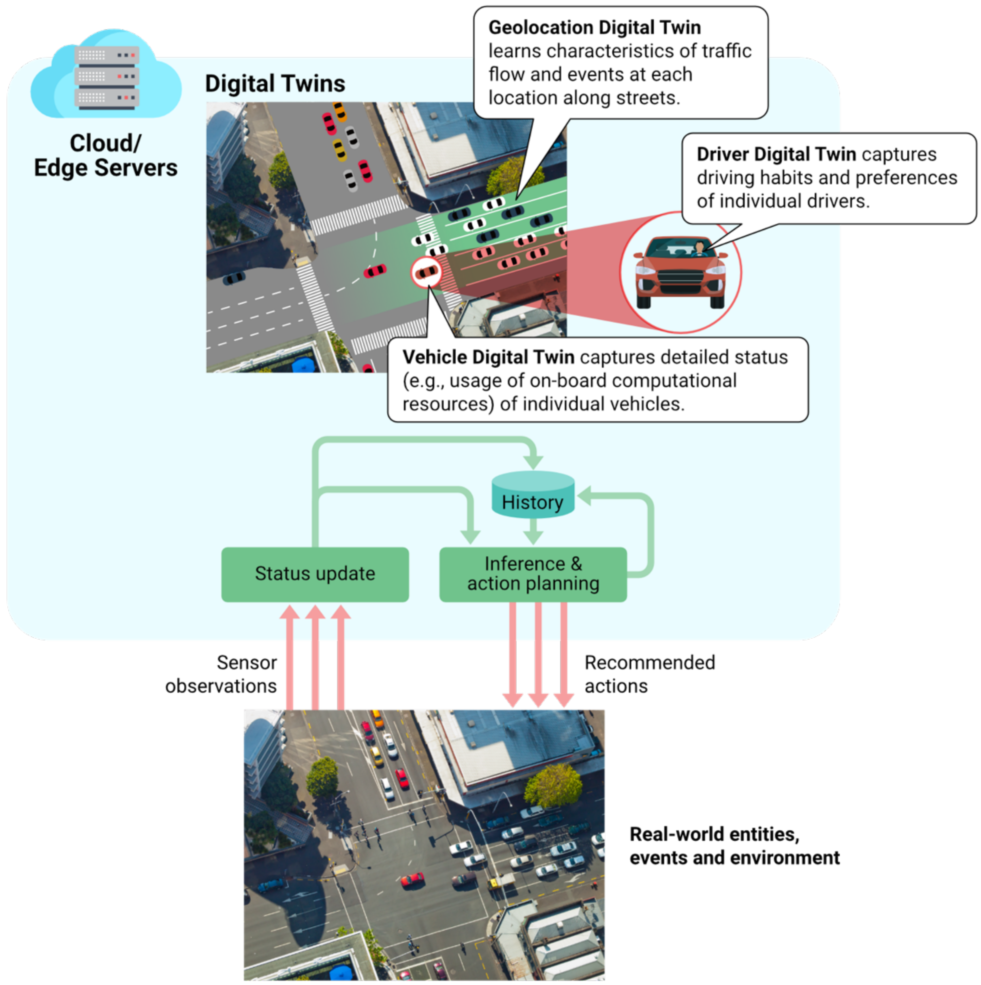

Figure 1 Overview of the digital twin concept

Digital twins are high-fidelity digital representations of real-world entities, events and environments that affect people’s mobility (generally referred to herein as observed entities). Figure 1 shows the overview of the digital twin concept in the AECC context. The bottom part of the figure illustrates the real-world roadway environment. It consists of a myriad of observed entities, such as vehicles, drivers, pedestrians, bicyclists, road infrastructure, parking spots, potholes, etc. In some use cases, road traffic events (e.g., traffic jams or lane closures) or environmental factors affecting road traffic (e.g., weather conditions) can also be considered as part of the observed entities. The observed entities are mirrored in digital twins in an AECC system. Digital twins are defined by a set of parameters that represent their physical counterparts' characteristics, states and behaviors. The observed entities are monitored over networks (e.g., by collecting sensor data from vehicles and road infrastructure) to synchronize the digital twins with real-world conditions whenever possible. This makes the digital twins collectively serve as a comprehensive digital representation of the real-world roadway environment. Digital twins may also save the historical state of observed entities to maintain snapshots of the past.

Automotive Digital Twin Use Cases

Edge computing allows us to enable the following digital twin use cases:

1. Traffic Engineering Using Road Event Digital Twins

In this use case, street events are collected, and the digital twin of the road is updated to show the current condition of the road. Street events can also be accumulated to serve as a historical reference. This data can then be used for traffic engineering.

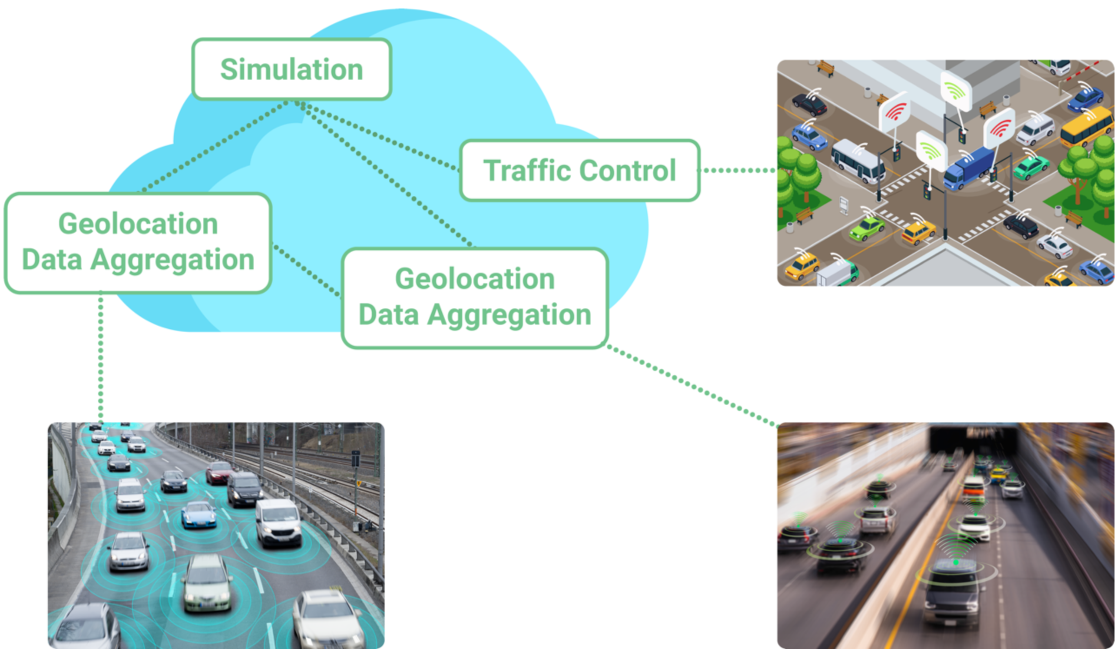

Figure 2 Traffic engineering using road event digital twins

2. Vehicle Resource Sharing Using Vehicle Digital Twins

The emerging edge AI concept, where AI inference models are run on the edge, aims at improving the quality of services by using smaller models that are localized and/or personalized. While the models are smaller in size, they will still require a considerable amount of computing power. Luxury cars may be equipped with high-power GPUs that can act as edge computers to run edge AI to fulfill demand.

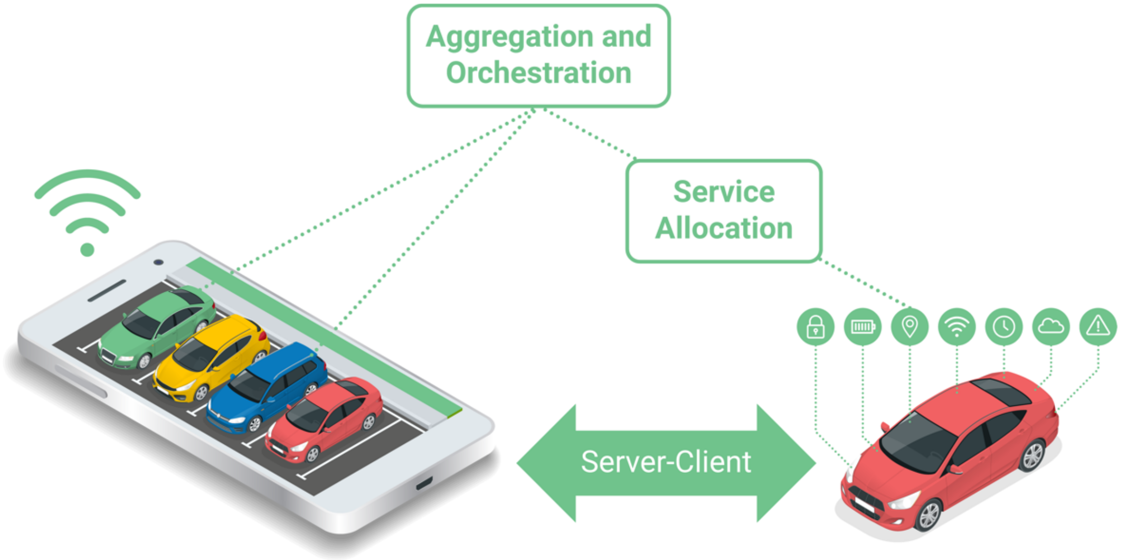

Figure 3 Vehicle resource sharing using a vehicle digital twin

3. Personalized Adaptive Cruise Assist Using Driver Behavior Digital Twins

Drivers of vehicles are monitored, and data about their driving behavior and physical condition, among other properties, is collected. By adjusting the model using the driver's data and inputs of the surrounding geo-location events, personalized cruise assist recommendations can be given to each driver.

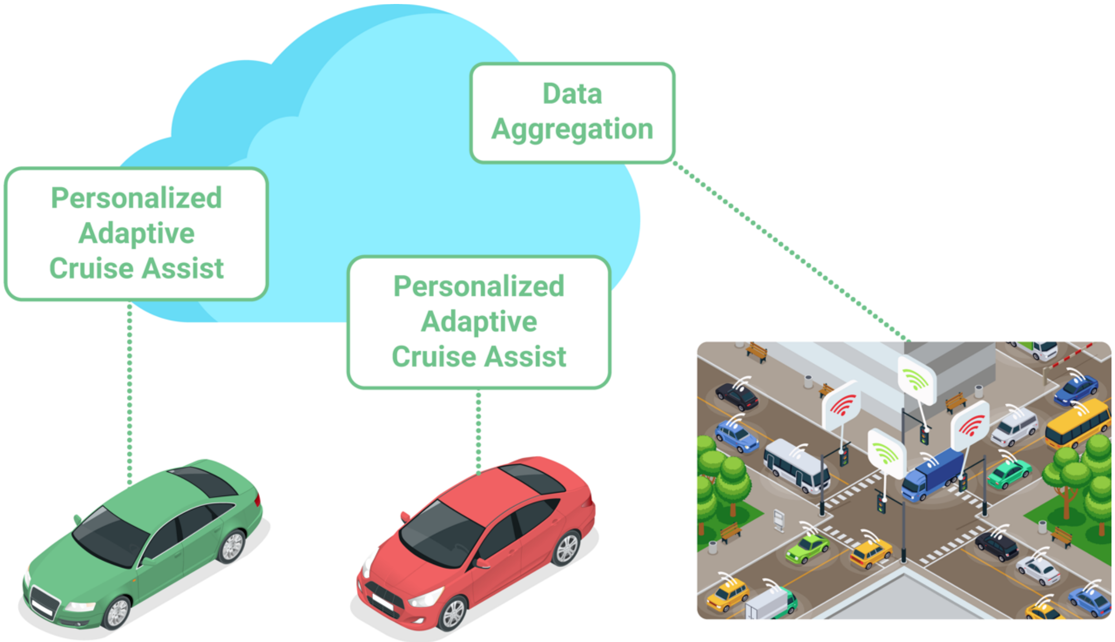

Figure 4 Personalized adaptive cruise assist using driver behavior digital twins

Leveraging Automotive Edge Computing for Digital Twin Use Cases

1. Low Latency and Low Jitter

Vehicles on public roads can move up to 160kph, which means that the use cases mentioned above need to utilize this digital representation per specific geo-location in a short amount of time. The network that computes these digital twins should maintain a consistent round-trip latency. Not only low average latency, but a constant latency with low jitter should be maintained from the moment of sensory input to the point of use, regardless of increased sensory sourcing from events like accidents or widespread natural disasters (e.g., fires, floods or blizzards). Moreover, heightened demand from in-vehicle applications should not cause additional service latency for any vehicle application.

2. High Fidelity and Efficient Data Transport

Automotive use cases of digital twins require sensory data to be efficiently processed into its digital form with minimum error. The network and computation architecture of edge computing is designed to prevent bottlenecks, especially those caused by overcrowded connections to centralized and/or distant processing centers.

3. Affordable Environment to Deploy AI Services

Current processing relies on clustered servers with limited supply, thus increasing the computation service price. The recent advancements in generative AI for processing and segmenting image and sensory data enable more distributed inference, such as by using fleets as far-edge. While this slightly increases the latency for individual data processing tasks, it can offset accumulated system-wide delays by utilizing many additional computing resources that would otherwise remain idle, such as when using fleets as far-edge. In this document, we define far-edge as an edge device that is deployed closer to the client.

Edge Computing Implementation Issues

1. Network Architecture

Sensor data needs to be collected periodically to maintain the fidelity of digital twin data. It is common for the number of clients and sensors within the network to change while maintaining the digital twin of road traffic. Disruption from the environment, such as in the case of natural disasters, should also be expected. These conditions make maintaining consistent latency challenging. This means that the network needs to be agile, allowing it to reconstruct dynamically to meet the latency requirement.

2. Computing and Storage Architecture

When vehicle fleets become not only consumers and producers of data but also computing resources, computing and storage architecture should be re-envisioned. As computation time is crucial in maintaining a constant latency, computing architecture will be designed to take less time to load data, such as by utilizing in-memory processing. Resources from multiple vehicles may need to be used in unison to achieve the required computing power while maintaining the requirements.

3. Orchestration and Application Development

AI processing is a core component of creating digital twins, especially as more tasks need to be autonomous. However, AI models that are notorious for taking up storage, memory and processing resources may need to be adapted to fit into the new edge computing architecture. Personalizing AI models and using fleets as computing resources will require a new way to develop and orchestrate applications.

Conclusion

Digital twins can be utilized for automotive use cases in many ways. Low latency and low jitter data transmission, high fidelity and affordability are essential in implementing these use cases. Moving forward, the AECC will analyze the requirements for these use cases in depth and propose technical solutions to fulfill the requirements.